Late Devonian and Early Mississippian Distal Basin-Margin Sedimentation of Northern Ohio[1]

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ABSTRACT. **Clastic sediments, derived from southeastern, eastern and northeastern sources, prograded westward into a shallow basin at the northwestern margin of the Appalachian Basin in Late Devonian and Early Mississippian time. The western and northwestern boundary of the basin was the submerged Cincinnati Arch. The marine clastic wedges provided a northwest paleoslope and a distal, gentle shelf-edge margin that controlled directional emplacement of coarse clastics. Rising sea levels coupled with differences in sedimentation rates and localized soft-sediment deformation within the basin help explain some features of the Bedford and Berea Formations. The presence of sand-filled mudcracks and flat-topped symmetrical ripple marks in the Berea Formation attest to very shallow water deposition and local subaerial exposure at the time of emplacement of part of the formation. Absence of thick, channel-form deposits eastward suggests loss of section during emergence.**

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INTRODUCTION

The Ohio Shale, Bedford, and Berea Formations of northern Ohio are clastic units which record progradational and transgressional events during Late Devonian and Early Mississippian time. The sequence of sediments is characterized by (1) gray mudshale, clayshale, siltstone, (2) gray-black mudshale, siltstone, (3) black mudshale, (4) gray mudshale, siltstone, very fine-grained sandstone, (5) red mudshale, (6) channel-form and blanket sandstone, and (7) gray, black mudshale. In this field trip preface I want to present an overview of the regional (northern Ohio) variation in these sediment characteristics based on previous studies and on my field observations, display paleocurrent information (much of which has not been previously published) about the coarse clastic sequences, and present paleoenvironmental interpretations about the record.

STRATIGRAPHY

The stratigraphy consists of portions of four formations. They are, in ascending order, the Chagrin and Cleveland Members of the Ohio Shale Formation, the Bedford Formation, the Berea Sandstone and the Sunbury Shale Member of the Cuyahoga Formation (Fig. 1). The position of the systemic boundary between the Devonian and Mississippian is controversial. Pepper et al. (1954) and DeWitt (1970) placed it at the base of the Bedford Formation. Eames (1974) placed it at the top of the Berea Formation, and Conkin et al. (1980) placed it on top of the Bedford Formation.

The Chagrin Shale Member of the Ohio Shale Formation, named by Prosser (1903), is a wedge-shaped body of gray mudshale, clayshale, siltstone, and fine-grained sandstone that lies between the Huron and Cleveland (black shale) Members of the Ohio Shale Formation. The wedge thickens eastward to western Pennsylvania where it becomes the Riceville Shale. It thins westward and pinches out near the Huron River. The overlying Cleveland Shale, named by Newberry (1870), thins both to the east and west from maximum thickness west of Cleveland.

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The Bedford Formation (Newberry 1870) is the most lithologically varied formation of the group. It is comprised of gray and red mudshales, siltstone, and very fine-grained sandstone. The Bedford Formation thins both to the east and west and reaches its maximum thickness in the Cleveland area.

The Berea Formation (Newberry 1870) is a fine- to medium-grained lithic sandstone. In the Cleveland region, the upper part has a blanket geometry; the lower part has thick, channel-form features of controversial origin. A thin blanket sand underlies channel-form units in outcrops west of Cleveland.

The Sunbury Shale Member of the Cuyahoga Formation is a thin, black shale unit of variable thickness that lies conformably on the Berea Formation.

LITHOFACIES DESCRIPTION AND PALEOENVIRONMENTAL INTERPRETATION

Six major lithofacies of the Upper Devonian and Lower Mississippian stratigraphic section are recognized in the Cleveland vicinity (Fig. 2). Regional position of the stratigraphic units representing these facies is indicated in Figure 3.

GRAY MUDSHALE-CLAYSHALE AND SILTSTONE LITHOFACIES. Light to medium-gray clayshale and mudshale with intercalated laminated and bedded siltstones comprise the lowest stratigraphic lithofacies exposed in the Cleveland region. This represents the Chagrin Shale. Thin bluish gray, dark gray to black bands and marcasite and clay ironstone concretions also are present (Nelson 1955). Fossils include mainly inarticulate and articulate brachiopods and trace fossils, occasional bivalves, gastropods, nautiloids and echinocarid remains and traces, rare bryozoans, echinoderms, sponges, and fish remains (Coogan et al. 1986). Siltstones thicken and concentrate (up to 25% of section) eastward where they are generally massive, bioturbated, vertically burrowed and occasionally show slight hummocky cross-bedding near the tops. Siltstones thin westward in the Cleveland region where they comprise <10% of the section and occur as both continuous units and very thin (0.5-1.0 cm) structureless lensoid pods along with discoidal siderite concretions. Some sandy siltstones with

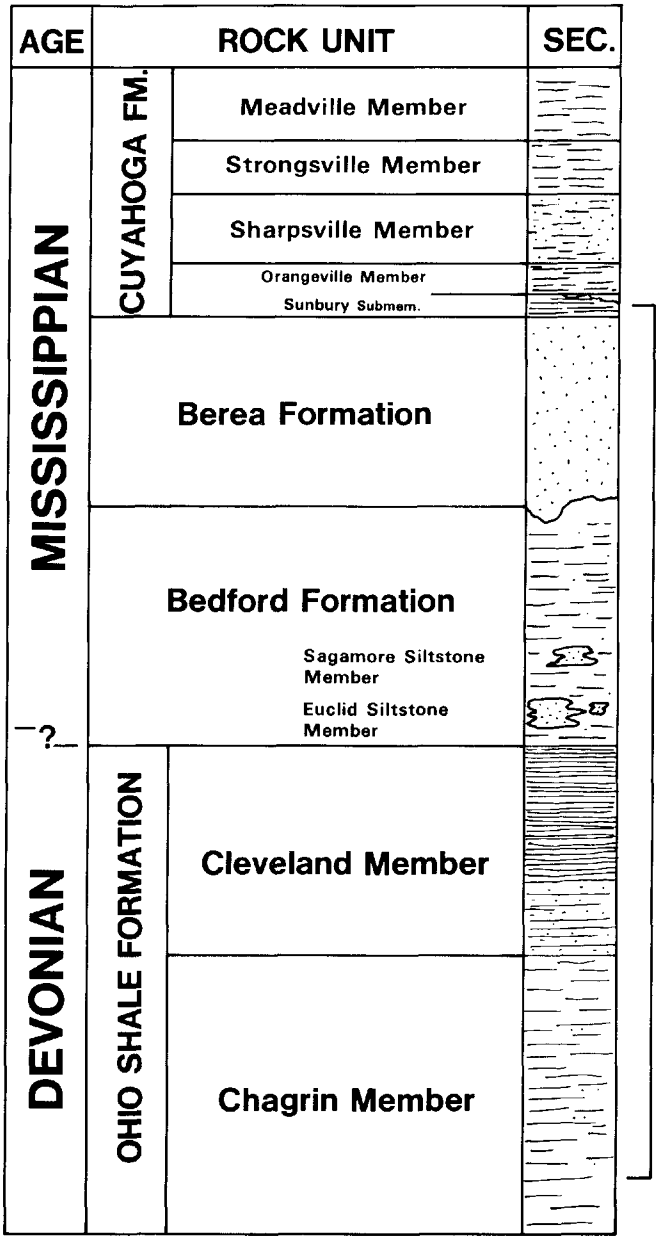

FIGURE 1. Generalized stratigraphic column for Upper Devonian and Lower Mississippian rocks in the Cleveland area. Portions of the section described are bracketed.

load and groove casts, articulate brachiopods, plant remains, burrows, swaley cross-stratification, and symmetrical ripple occur in one area along the Cuyahoga Valley and in outcrops between the Grand River and Ashtabula, Ohio. These units record paleocurrents to the northwest and west (Fig. 4). A thin fossiliferous pyrite layer on top of part of the facies occurs in outcrops around the plateau margin between the Cuyahoga and Chagrin River Valleys (Hlavin 1978, Mausser 1982).

The facies likely represents a shallow prograding shelf (Mausser 1982). An eastward increase of sandy shales with increased frequency of brachiopod zones and symmetrical ripples just below Cleveland Shale suggests shallow water conditions (Nelson 1955). Szmuc (1970) recognized deepening conditions toward Cleveland evidenced by trace fossil changes. Lewis (1976) proposed a northwest paleoslope to allow for dispersal of silts on, off, and marginal to the distal edge of the Chagrin. Potter et al. (1979, 1980), envisioned deep waters marginal to black shales where coalescing submarine fans accumulated along and at the base of a paleoslope. However, residual hummocky cross-bedding that survived active bioturbation suggests storm activation and deposition above storm wave base. Hannibal and Feldmann (1983) evoked storm events for some siltstones that contained escape traces of echinocarid arthropods.

GRAY-BLACK MUDSHALE AND SILTSTONE LITHOFACIES. This lithofacies is distinguished by thin laminae and thin beds of gray siltstone intercalated with gray and black mudshale laminae and beds. Regionally, the facies represents the lower part (informal Olmsted Shale) of the Cleveland Shale. It pinches out eastward between the Gray Mudshale-Clayshale and Siltstone lithofacies and overlying black mudshales, and westward between black mudshales near the Huron River (Fig. 3).

The facies is thickest in the western Cleveland area where the frequency of siltstone laminae and beds reaches a maximum. Siltstones may show graded bedding with various combinations of Bouma turbidite horizons (Broadhead et al. 1982), rare flutes and prods, frequent grooves and swaley cross-stratification, trace fossils, and locally bioturbated tops and bottoms. Multitudinous alternating silt and black organic laminations occur.

The facies represents a siltstone turbidite and mud fill in a distal shallow basin. Directional data (Fig. 4) suggest sediment input off (northwestward), subparallel (westward), and parallel (southwestward) to a northwest paleoslope, as the silt sediments followed the longitudinal axis of the basin suggested by the lineation of the Cleveland Shale isopachs in Figure 5. Mausser (1982) suggested that the turbidite sequence was derived from a river directed from the northeast, with these sediments bypassing the main Chagrin (Gray Mudshale-Clayshale and Siltstone lithofacies) to the east. Moreover, such bypassing also allowed some time for reworking with little deposition to concentrate the pyrite zone traced on top of part of the Chagrin. Active storms on the shallow shelf margin, however, may have initiated the sediment influxes that behaved as turbidites off and parallel to the paleoslope. Storm activity could also have developed a fossil lag deposit as well. Distally, the basin was slightly deeper but still shallow, as attested by active bioturbation, occasional inclined burrows and, as noted by Mausser (1982), some truncated internal stratification that developed because of storm effects. Extensive swaley cross-stratification (which also causes truncation) in the siltstones, however, suggests deposition by fairly unidirectional basin currents. This, along with the absence of symmetrical ripples, may indicate deposition below storm wave base.

BLACK MUDSHALE LITHOFACIES. This facies occurs at several stratigraphic horizons in the Cleveland area and is represented by the upper units of the Cleveland Shale and by the Sunbury Shale. The Cleveland Shale is the more conspicuous and extensive unit of the area. Isopach contours of the Cleveland Shale (including the lower Gray-Black Mudshale and Siltstone lithofacies — Olmsted Shale) delineate a northeast-southwest thick zone in the Cleveland vicinity which then turns abruptly south in western areas (Fig. 5). The facies thins eastward and rests, in sharp contact, on the Gray Mudshale-Clayshale and Siltstone lithofacies (Chagrin Shale). Slight

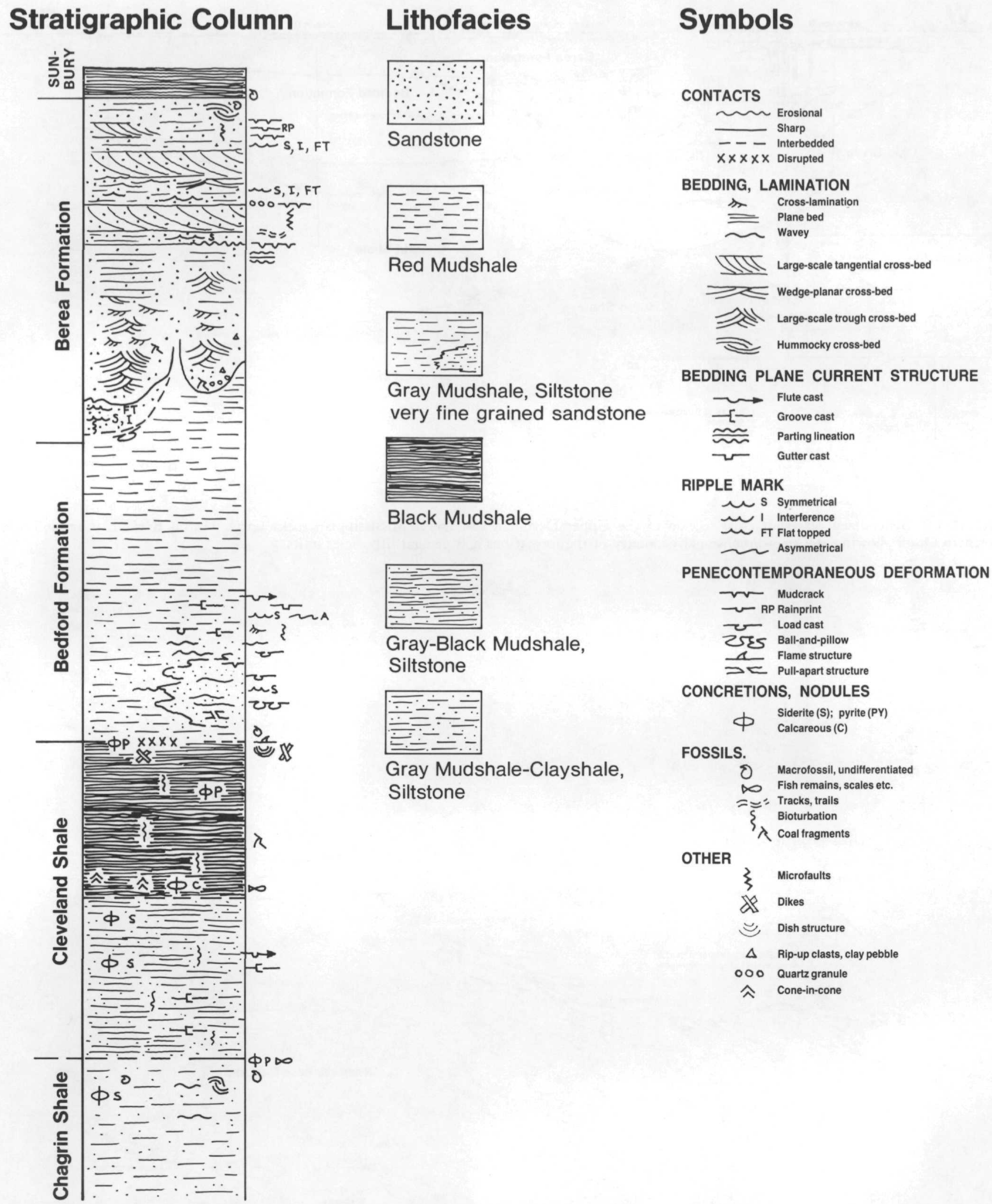

FIGURE 2. Generalized columnar section of part of the Ohio Shale Formation (Chagrin Shale and Cleveland Shale), Bedford Formation, Berea Formation, and the lower Cuyahoga Formation showing lithofacies subdivisions, contacts, fossil horizons, and sedimentary structures.

thickening of the Black Mudshale lithofacies occurs in the Grand River area, but it thins east of there.

The Cleveland Shale representative of the facies is predominantly composed of quartz-pyrite-illite-chlorite and organic matter, and is fissile in the Cleveland region (Nelson 1955). It becomes more silty and micaceous eastward and more organically rich and calcareous westward. It is extensively bioturbated (Jordan 1984) and contains sparse marine fossils that include inarticulate and articulate brachiopods, gastropods and, locally, sharks and

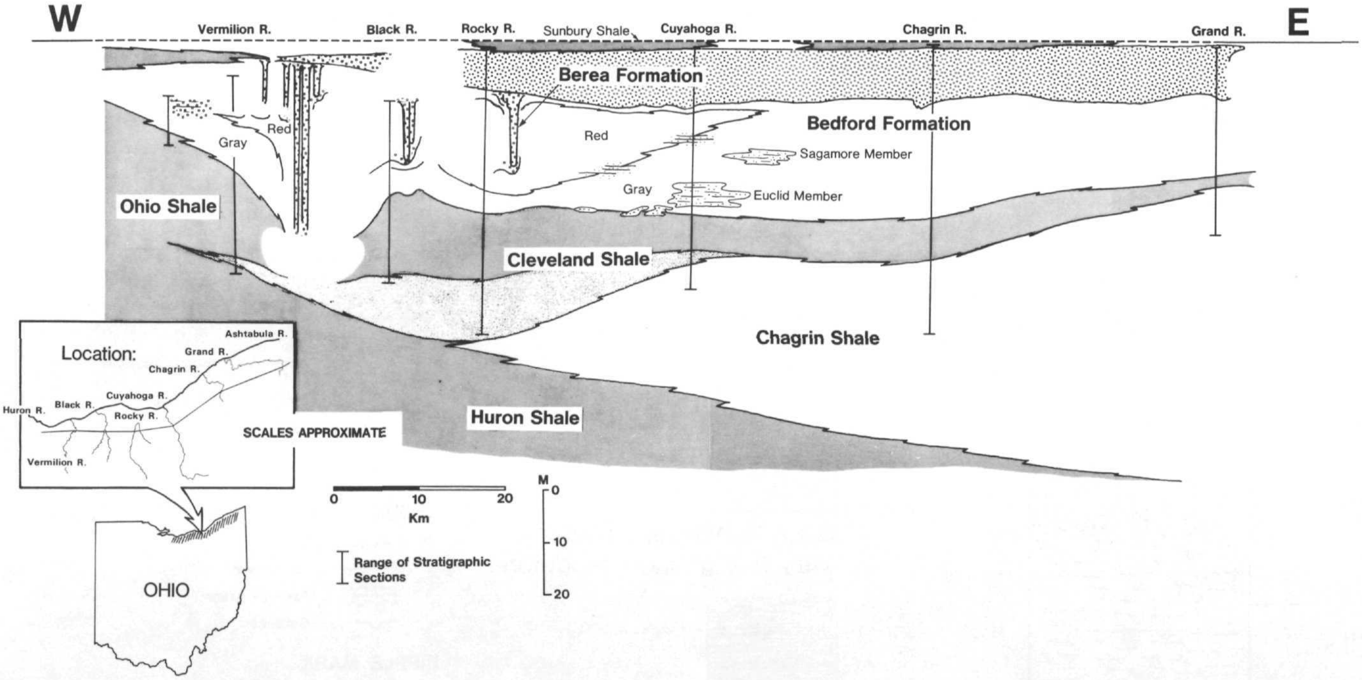

FIGURE 3. Generalized east-west cross-section of the Upper Devonian and Lower Mississippian rocks units, Huron River to Grand River, northern Ohio, showing the two-dimensional geometry of the formations and general lithofacies units.

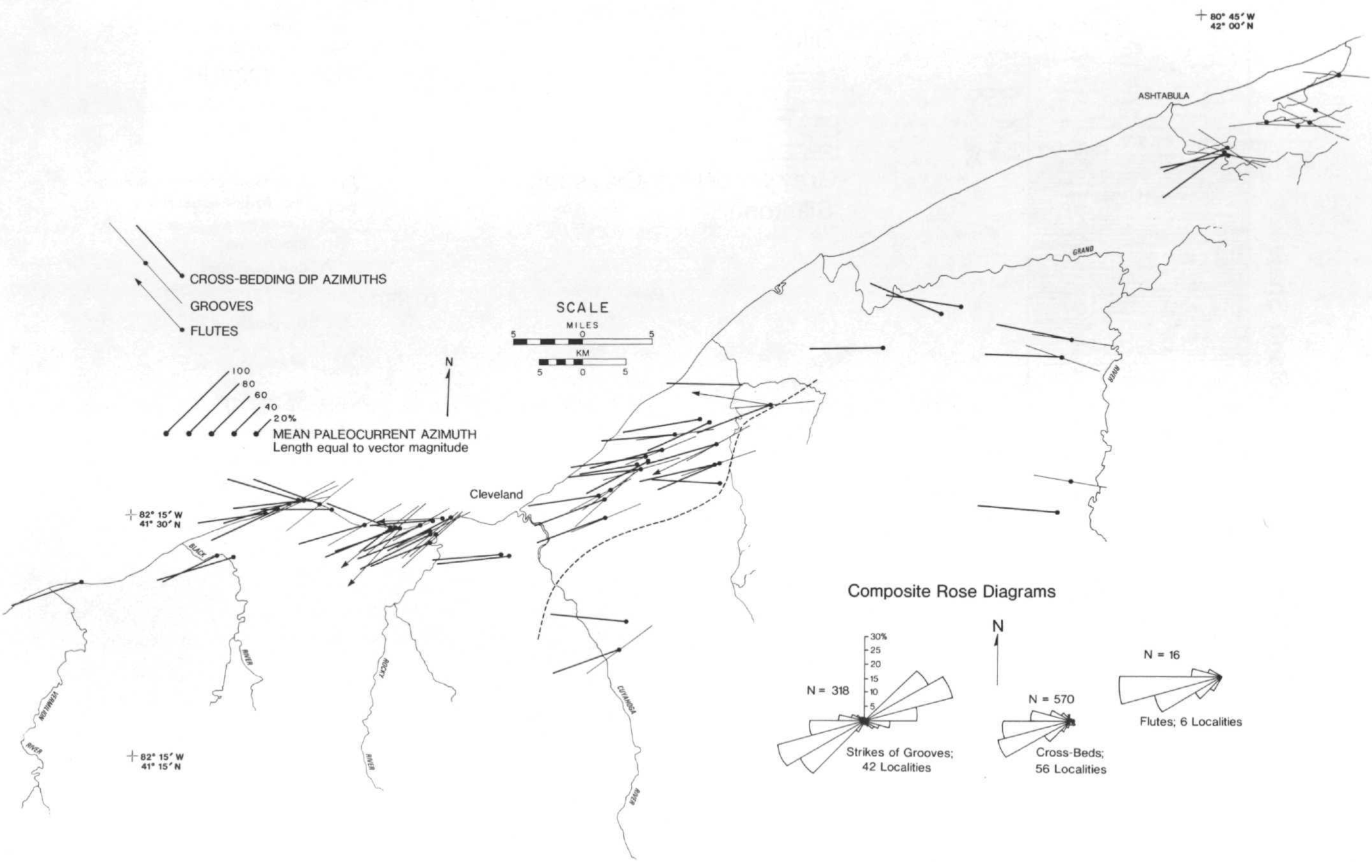

FIGURE 4. Vector means of paleocurrents in the Chagrin and Cleveland shales. Directions of the symbols represent means of the summation of all measurements at that point (locality). Symbol length represents a measure (consistency ratio) of the dispersion of directions around the mean. Shorter lengths suggest more widely scattered measured directions. Northwest directed flow changes west-southwest along the paleoslope (northwest of dashed line that represents eastward pinchout of the Gray-Black Mudshale, Siltstone facies). Current directions then turn southwest near basin axis west of Cleveland. Cross-bed orientations show some departure from those of groves on flutes west of Cleveland.

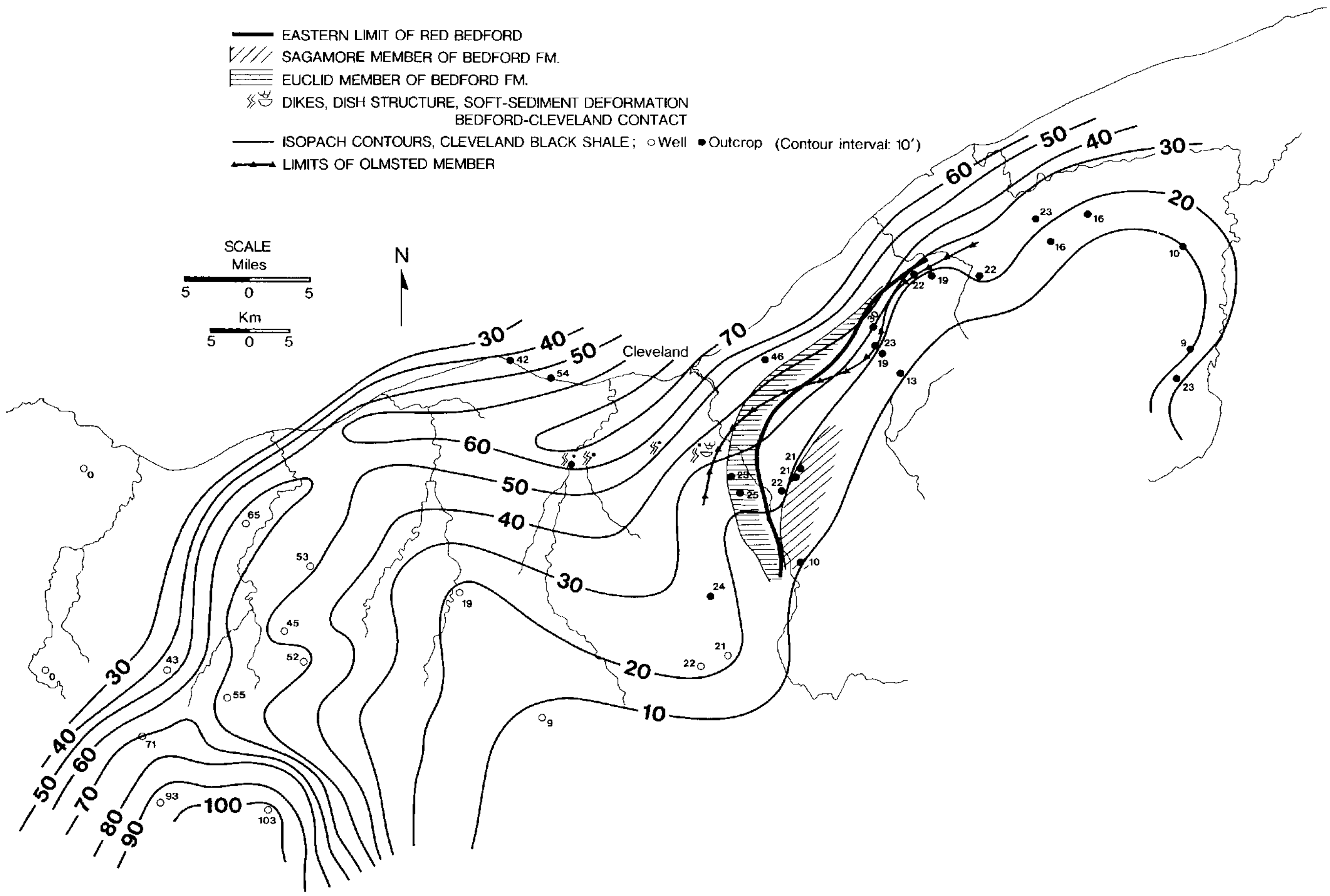

FIGURE 5. Isopach map of the Cleveland black shale based on studies by Lewis and Schwietering (1971). Positions of some superimposed clastic events are shown also (listed in stratigraphic order). Note the stacking of eastward pinchouts with thick clastic units (Euclid and Sagamore) which helps delineate the margin of the distal basin with a gentle paleoslope or shelf edge.

placoderms. Carbonate lenses, cone-in-cone structure, and nodular limestones occur in western outcrops. Ball-and-pillows, siltstone dikes, contorted silt lenses, and disk structure occur locally at the top of the facies, and the upper contact often dips near outcrops of thick sandstones (Berea).

Black mudshale representing the Sunbury is seen only in several outcrops. The facies generally includes gray shale and siltstones near the base, directly overlying rippled or hummocky cross-bedded sandstones. Black shale interfingers directly with top sandstones in one western outcrop. Eastward, the facies gives way mostly to gray mudshales (Orangeville Shale Member of the Cuyahoga Formation).

The lithofacies represents mud sediment accumulation in a distal shallow basin. Silt and terrestrial organics moved down and around the shelf margin into a basin undergoing increased plankton production and perhaps anoxia conditions in stratified waters (as modeled by Ettensohn and Barron 1981). The extensive bioturbation of the black mudshales led Jordan (1984) to believe the aerobic-anaerobic boundary was below the sediment water interface. Perhaps, as has been suggested for the Black Sea Basin (Smirnov 1958), sedimentation rate and rapid burial of organic matter as well as reducing conditions in the sediments, were important. Multitudinous silt laminations and thin beds separating black mudshale laminations seen in the Cleveland Shale may record such rapid accumulations and burials of organics.

A sea level rise extended basin conditions eastward and black muds were deposited over the Gray Mudshale-Clayshale and Siltstone lithofacies (Chagrin Shale). Schwietering (1978) suggested that this may have represented an infilling stage spreading eastward, or seaward, during a still stand of sea level by shallow water black mud facies that developed along the interior margin of an epicontinental sea. Loss or diversion of clastic sediment supply and local basin subsidence could also account for the change. A rise of sea level seems most plausible; the deepening waters across the shelf provided space for accommodation of the next clastic sequence (Bedford).

GRAY MUDSHALE, SILTSTONE, VERY FINE-GRAINED SANDSTONE LITHOFACIES. The broadly defined lithofacies generally covers facies subdivisions of the gray units of the Bedford Formation that have been adequately defined by Kohout and Malcuit (1969), Pepper et al. (1954), and Mauser (1982). The lithofacies represents the coarse clastic sequence above the black mudshales of the Cleveland Shale located mainly on the plateau between the Cuyahoga and Grand rivers. Siltstones thin rapidly westward (to west branch of the Rocky River) and are replaced by increasing amounts of gray mudshale.

A gradational lower contact of interbedded black and gray mudshale with bioturbation features and thin brachiopod zones and siltstones with flame structures and load casts occur in eastern Cleveland outcrops. In western Cleveland, symmetrically rippled sands cover pryritized bivales in black mudshales. A fossiliferous carbonate layer on black shale is recognized west of Cleveland.

Distinctive coarse clastic sequences comprise other parts of the lithofacies. One is a thick series (2-11 m) of siltstone and very fine-grained sandstone (Euclid Member) which outcrops in an northeast-southwest arcuate zone (Fig. 5). It rises in section, and thins and disappears northeastward, eastward and southward. A similar but smaller and stratigraphically higher unit (Sagamore Member) parallels this trend. Thicker beds of these units pinch and swell, some split into thinner units, and most show indistinct to massive bedding, conchoidal fracture and pull-apart structures, ball-and-pillows and sometimes large-scaled undulating upper surfaces. Thinner intercalated beds may be rippled symmetrically. Small cross-beds, scours, and mudcracks have been recognized by Kohout and Malcuit (1969). Locally, thick massive units dumped into soft black mudshale (Cleveland Shale) and produced deformed channels, microfaulted ball-and-pillows, and siltstone dikes. The remaining dominant subfacies of mudshales and micaceous-carbonaceous siltstones display frequent load-casts and small-scaled grooves, infrequent flutes, and rare gutter-casts. Internal bedding is often massive, sometimes graded and, in thinner beds, cross and wavey-laminated. Symmetrical ripples with consistent wavelengths and directions are common.

Initial sandy silts were spread over soft black muds covering an eastern shelf and carried into the distal shallow basin area where they were symmetrically rippled. The younger, coarse portion of the lithofacies developed mainly on and marginal to the shelf. Siltstone characteristics (similar to those described by Duke (1985)) suggest development by standing waves created during storm-surge events that had a strong unidirectional northwest flow (Fig. 6). This pattern was subparallel to northeastern shoaling areas as indicated by consistent symmetrical ripple trends. This partially simulates a coast-parallel directional flow that is suggested from studies of modern shelves (Swift and Niedoroda 1985). Flow direction changed west to southwest down the paleoslope. It then turned southward, probably controlled by strong basin currents parallel to the shelf break. Suggested origins of the thick sandy siltstones of the Euclid include a barrier bar (Pepper et al 1954),

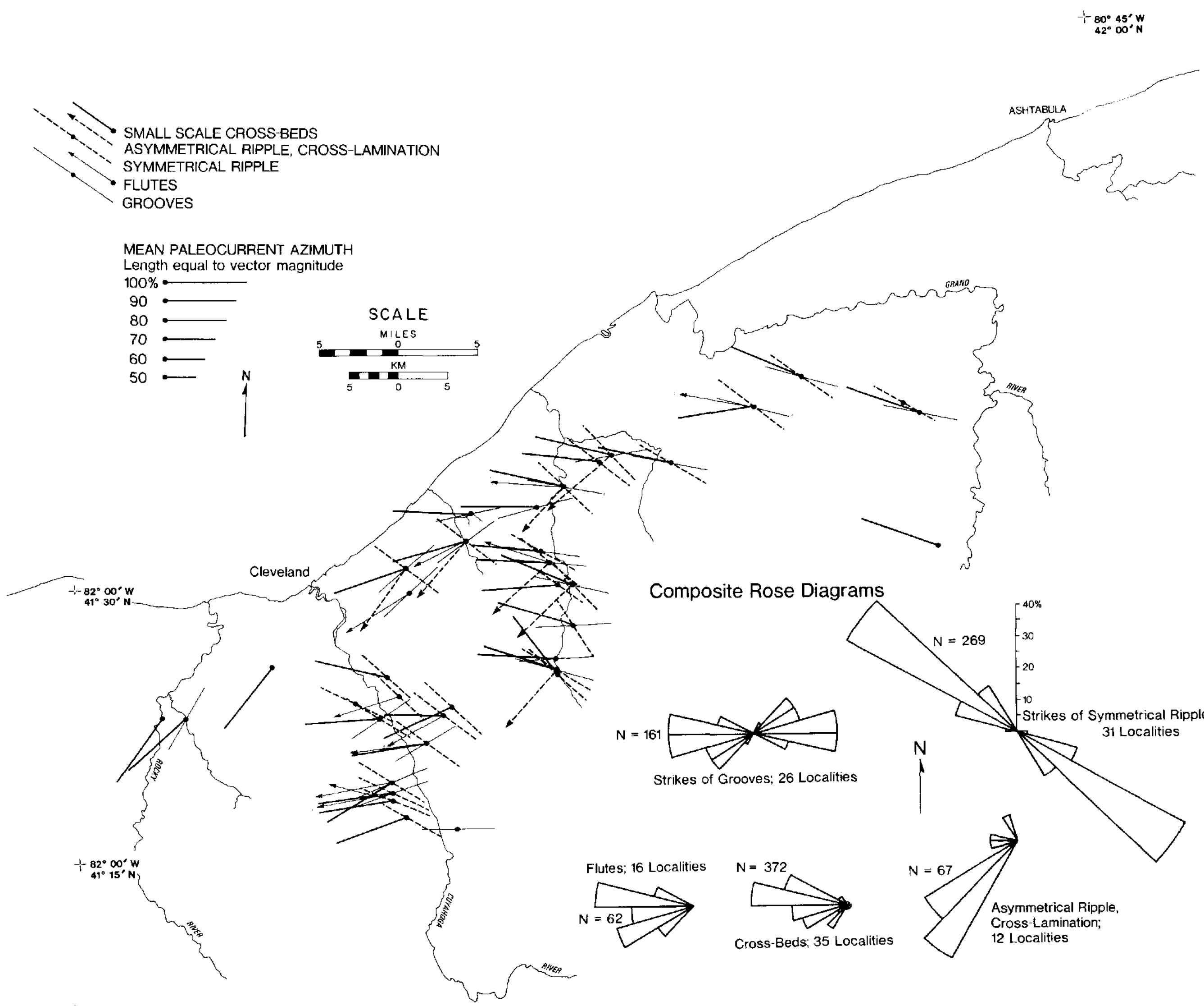

FIGURE 6. Vector means of paleocurrents in the Bedford Formation. Current directions, indicated by flutes, grooves and cross-beds, indicate movement off the paleoslope. They then turn southwest along the shelf edge and southward in the basin. Symmetrical ripples show consistent trends on the shelf, suggesting shoaling northeastward.

barrier and beach (Kohout and Malcuit 1969), and distal bars on the edge-of-slope break of an advancing delta platform (Coogan et al 1981). The dominant structures of these units suggest rapid deposition and perhaps resulted from storm events. Materials of limited size range were entrained, locally moved, and stacked at the sediment shelf-basin break where strong contour currents helped maintain them in place. Some of these rapidly emplaced deposits slumped and plowed into soft basin black muds causing local deformation. Silts younger than Euclid spread basinward for short distances.

RED MUDSHALE LITHOFACIES. Brownish red mudshale is conspicuous because of color and extensive fracturing. The lithofacies, representing part of the Bedford Formation, is thickest in the Cleveland vicinity but thins westward and disappears near the Vermilion River. It thins, interfingers with, and pinches out eastward over some of the upper Gray Mudshale, Siltstone, Very Fine-grained Sandstone lithofacies. Red mudshale is gradational with gray mudshale below it. Usually, a 1-2-m unit of gray mudshale separates the red mudshale from the overlying Berea Sandstone.

The lithofacies represents basin accumulation of sediments rapidly emplaced in distal shallow open waters below wave base (Lewis 1976). Mausser (1982) suggested a shallow sediment-starved basin that was oxic and received reduced contributions of organic matter. Other interpretations include those of Pepper et al. (1954) who considered the red muds to be derived from northern sources brought south as a delta, and Kohout and Malcuit (1969) who suggested that a wind tidal flat developed behind a barrier bar. The notion of distal basin accumulation is supported by its emplacement over thick, former marine black and gray mudshales, the lack of sedimentary structures indicating tidal origin, and evidence of intercalation of thin siltstones and red laminations in the basin, in part concomitant with deposition of the upper Gray Mudshale, Siltstone, Very Fine-grained Sandstone lithofacies. Some sediment influxes may have been from the northeast following strong southerly directed currents (indicated in shelf marginal siltstones). Concomitant, shelf-derived silts disappeared quickly in the basin. This might have been a result of a slow down of supply or perhaps a result of mixing in the ambient muddy waters of the basin. Red color of the organically poor sediments may have been original, but likely was produced diagenctically.

SANDSTONE LITHOFACIES. The lithofacies is comprised of fine- to medium-grained, moderately-sorted, often calcareous sandstone. It represents stratigraphically the Berea Formation, and occurs in two geometric shapes: isolated thick deposits with sharp convex boundaries (often referred to as "channels") in gray-red mudshale, and as blanket-type deposits. A basal blanket deposit occurs west of the Black River and is absent in the Cleveland area. The variably thick accumulations occur in the Cleveland vicinity and over the blanket sandstone to the west. A widespread upper blanket sand occurs across both the red and gray mudshale and several thick sandstones bodies. These occur mainly eastward over the extensive Gray Mudshale, Siltstone, Very Fine-grained Sandstone lithofacies (Bedford) where the red mudshales are absent.

Symmetrically rippled, thin bedded sandstones with thin mudshale interbeds comprise the lower blanket deposit. Ball-and-pillows, some as large as 3.5 m but most 20 to 50 cm in size, characterize the lowest sands over gray mudshale. Two to three stages of microfaults occur in the ball-and-pillows. Symmetrical ripples with wavelengths of 6 to 10 cm, some with flat tops and others with interference patterns, are interbedded with thin, bioturbated mudshales. A pronounced north-south, ripple-crest trend is generally consistent in most areas (Fig. 7). Where closely spaced, stacked ripple sets are seen, they climb in an eastward direction. In many instances, rippled units have been tilted to high angles beneath thick sand bodies. Overturned rippled-sandstone beds are known from several localities west of the Vermilion River. The sequence is interpreted as a thin sand sheet developed on a shallow marine shelf. Sources might have been distal delta front sands from prograding (younger) distributary bodies.

Isolated, discontinuous, variably thick (mostly from 4-25 m; one near 60 m) sandstone bodies occur where stratigraphically lower black, gray, and red mudshales are thick. Orientations of sedimentary structures as well as the lineation of the short, elongate units are generally northwest in the Cleveland area, and northwest, west, and slightly southwest in the major quarry area between the Black, and Vermilion rivers (Fig. 7). Large-scaled (20 cm-1.5 m) trough cross-beds, plane beds with parting lineation, and small scaled cross-beds are the common structures. Occasional coal-fragment concentrates and rip-up clasts of bent gray and red shale occur occasionally as scattered fragments or thin lenses in cross-beds. Normal faults are common in and at the edges of "channels." These often extend into the underlying mudshales and help shape angular and irregular contacts. Erosional contacts are absent and underlying mudshales are often deformed, including upper beds and contact of the Cleveland Shale.

Pepper et al. (1954) considered these units to be cut channels associated with the red Bedford delta derived from the north. However, evidence of emplacement directed from the east and northeast, extensive soft sediment deformation, and a close association with marine blanket sands suggests a marine distributary system of sands constructively deposited in areas of thickest black, gray, and red muds of the gentle slope and distal basin (Lewis 1976, 1986). These sands were accommodated because of soft sediment deformation and faulting and tilting of thick underlying mudshales including the Cleveland Shale. Although bedform migration took place to create various vertical sequences, some penecontemporaneous adjustments occurred to allow room for easily moved sands to accumulate. Later adjustments of faulting helped encase and preseve most of the thick units in the basin-type setting. Eastward, a relative land rise cause the spread of regressive sands. Continued erosion perhaps allowed destruction of Berea sources and, as noted by Prosser (1912), erosion of some Bedford sediments to the northeast.

The upper blanket lithofacies occurs mainly between the Cuyahoga and Grand rivers (east of which it disappears), and rests mainly on the Gray Mudshale, Siltstone, and Very Fine-grained Sandstone lithofacies and occasionally gray (over red) mudshales of the Bedford. It

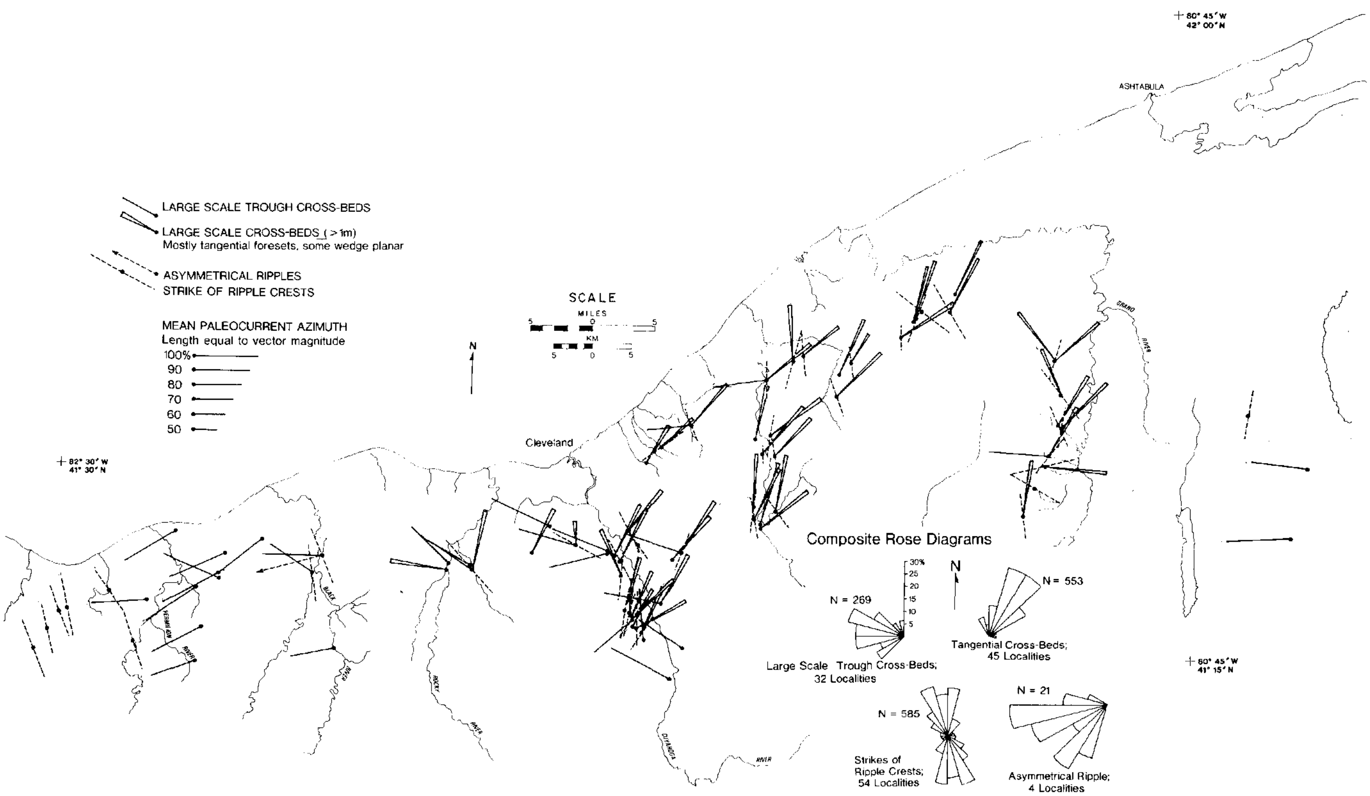

FIGURE 7. Vector means of paleocurrents (cross-beds and ripple marks) in the Berea Formation. A northwest-west-southwest flow is indicated by large-scaled cross-beds of the thick channel-form units. Large scaled cross-beds with mostly tangential foresets of the upper blanket sandstone suggest flow northwest-north, but mostly northeast over the shelf. Symmetrical ripple trends west of the Black River are in the lower blanket sandstone and show a consistent, nearly north-south strike. Ripple trends of the upper blanket sandstone on the shelf are highly variable.

extends westward between the Cuyahoga River and west branch of the Rocky River where it overlies gray mudshale of the uppermost Bedford and truncated units of several thick sandstone bodies. Separate, blanket-type sandstones cover several thick sandstone bodies in western outcrops. These display characteristics similar to originally horizontal sandstones that directly underlie several of the thick sand bodies.

Bedforms of the blanket include large-scaled (1-4 m) cross-beds that alternate with horizontal, symmetrically rippled beds comprising packages 0.7 to 4 m thick. Trough cross-beds with tangential bases dominate although some units are tabular, wedge-planar and rarely (one locality) low-angled. Occasional granule lags occur on truncated cross-bed tops. Cross-bed troughs are generally 3 to 5 m wide but occasionally may exceed 30 m. Cross-bed orientations are directed mainly northeast in the plateau region and north to northwest in western Cleveland areas (Fig. 7). Thin sandstones with symmetrical ripples of varying wavelengths and widely scattered strikes are often interbedded with mud laminations and thin bioturbated mudshales. Occasional mud cracks and flat-topped and double-crested ripples are present. Some ripples can be traced into tangential cross-bed troughs; others seem to be gently overridden by the cross-beds. Thickness of cross-bed sets decreases in northeast exposures near the Grand River. These are accompanied by more numerous ripple zones, occasional rain prints, rare wrinkle marks, and multiple horizons of sand-filled mud cracks suggesting repeated exposure. Additionally, rare trilobite resting marks have been noted in the Cleveland region, and hummocky cross-beds at the top of several sections.

The lithofacies represents sediment deposition on a shallow shelf during submergence. Initial transgression, following either stabilization or a slight drop of sea level that allowed regressive marine distributary infusions into the basin, planed off part of these emplacements (Lewis 1986). With continued submergence, new and locally derived sands were superimposed on former Bedford storm deposits and moved across local mudcracked surfaces, where they intermingled with some small channels (currents directed northwest and west) as they spread a sand flat over the shelf. Large, barchan-shaped subaqueous dunes developed periodically during strong, multiple storm events and migrated essentially northeast and north. Tides modified frequently formed wave ripple sets and some cross beds. Overall, the repetitive stacking of large, planed-off, cross-bed units separated by rippled beds suggest a record of multiple episodic sea level rises. Also, repeated units of cross-bed, ripple beds and sand-filled mud cracks in outcrops to the northeast suggest sea level variation, possibly associated with small multiple uplifts of the local region. Aeolian conditions were considered for some of the large cross-bedded units of the facies by Clifton and Dingler (1984) and Lewis (1986), but preservation would have been difficult under transgression. Potter et al. (1984) suggested that the lithofacies represented fluvial or tidal-channel origins.

The entire lithofacies between the Cuyahoga and Grand rivers records north to northeast migration of sands on a peninsular-like shelf built over former shelf areas. Sands locally migrated into soft mud and silt accumulations along the eastern shelf margin (near the Grand River valley) and then stopped. This separated Berea sands from storm-activated silts eastward (Berea, according to Szmuc (1970)). Blanket deposits over thick Berea units in far western outcrops display symmetrical ripples with large wavelengths and cross-beds that flowed southwest, perhaps a result of current motions along the shelf margin. Mud ripples, flame structure, and larger injection of gray and red muds around bulbous sands suggest that basin muds were still soft during emplacement.

Submergence continued accompanied by local storm reworking of upper Berea sands into hummocks and upward gradation into gray mud shales and the discontinuous siltstones and black shales of the Sunbury Shale. Sea level rise might have been rapid, coupled with complete loss or diversion of sand supply.

LITHOFACIES EQUIVALENCY. Some idea of the equivalency of the lithofacies can be recognized by the application of Walther's Law (Walther 1884) which states that the vertical facies that can occur together are those that developed laterally to one another. The notion presumes that sections are continuous and that there have been no significant stratigraphic breaks. Interpretation is also helped when information about depositional strike or source area is recognizable. Various lithofacies recorded in the Cleveland vicinity are, at best, continuous in the suggested distal basin sequence. A northeast-southwest depositional strike is recognized by the presumed sediment shelf-basin break and the stacked sequence of events recorded along it, as recognized in Figure 5.

The oldest Gray Mudshale-Clayshale and Siltstone lithofacies (Chagrin Shale) derived from the east is essentially equivalent with part of the Gray-Black Mudshale and Siltstone lithofacies (Olmsted Shale). Some turbidites (siltstones) originated from the Chagrin clastic wedge, but others moved around its margin and were deposited longitudinally in the distal basin. Here, younger basin-filling took place whereas eastward, few deposits were added to the Chagrin. The sequence ended with transgression and the spread of the Black Mudshale lithofacies eastward over the pinchout of the Olmsted and the development of very sharp contacts on the depositionally inactive Chagrin. Initial deposits of the succeeding Gray Mudshale, Siltstone, Very Fine-grained Sandstone lithofacies were gradational with black muds and were essentially equivalent across the basin. Slumps of coarse siltstones deforming black muds also suggest time equivalency. The eastern coarse clastics were mainly equivalent with distal gray muds and thin silts, but equivalency of some upper siltstone units with Red Mudshale lithofacies of the basin can be demonstrated in the field. Eastward extension of red muds took place over non-depositional surfaces inactive with reduced storm redistribution of sediments.

Equivalency of sandstone lithofacies is difficult to demonstrate. Most complete sections are in western parts of the basin farthest from probable sources. From there, a sequence of basal blanket, thick units, and upper blanket sands gives way eastward to the middle and upper units, then mainly upper blanket sands. Significant erosion took place eastward, and thick sands accumulated westward (probably at different times) on former basin muds undergoing penecontemporaneous deformation. Much of upper blanket sandstone provides the strongest case for equivalency as sands spread across a broad shelf during submergence. The overlying finer silts, gray mudshale, and black shales are equivalent and were produced during the continuing submergence event.

SUMMARY

The local paleogeographic setting was represented by a prograding shelf with a northwest paleoslope that served as a partial margin for a shallow distal basin that also was shallowing westward toward the submerged Cincinnati Arch. A slight shelf-marginal topographic break controlled turbidites off and around the margin, turning them southwestward longitudinal to the basin axis, and helped control those directed from northeastern sources, adding to silts and organics filling the distal shallow basin. Clastic input was slowed or diverted during transgression of black muds onto the shelf deposits.

Deepening waters created space for accommodation of silt and sand clastics that poured over black mudshale of the shelf and distal shallow basin. The initial sediment-water interface was shallow enough to allow symmetrical rippling of thin sands, and soft enough to be disrupted extensively with rapidly emplaced or slumped units of silt and very fine sands. The shallow, shelf-slope break was the locus for thick silt and very fine sand accumulations. Storms delivered silt impulses mainly to the northwest, subparallel to shoaling shelf areas to the northeast. Swift currents moved along the break turning storm-generated sediment influxes southwestward while adding gray and red muds to the distal basin. Coarse clastic supplies decreased and basin muds spread over part of the shelf.

Fine-grained shelf sands influenced by the tides stabilized over soft basin substrate to the west. Fine- to medium-grained sands moved onto soft gray and red muds of the basin, deforming them during and after deposition and, along with faulting, preserved widely separate, thick, discontinuous, elongate sand bodies. The eastern shelf area was exposed, eroded, and did not preserve source environments.

The final transgression initiated with the upper sheet sands. Sands, generated from planation of thick bodies and possibly sources that had eroded earlier, migrated north and mainly northeastward along the locus of the former shelf break. A northeast peninsula was delimited between the margin and a small mud re-entrant northeastwards which, in turn, separated these medium-grained shelf sands from siltier, storm-generated Berea equivalents to the east. With continuing submergence, a slightly deepening sequence of gray mudshale and discontinuous silts grading upward to black mudshale was deposited directly on these shallow water sands that stopped accumulating with diversion or loss of sand supply.

FIELD TRIP ROAD LOG

The field excursion consists of nine stops in an area essentially between the Cuyahoga and Rocky rivers (Fig. 8). A stratigraphic column for each of the stops is shown in Figure 9.

Distance: km (mi)

cum.		inc.		
0.0				Start — Wolf Ledges ingress to I-77 North and I-76 West.
3.5	(2.2)	3.5	(2.2)	Stay right, pass I-277-76 exit to Barberton. Follow I-77 North to Cleveland.
27.7	(17.2)	24.1	(15.0)	Pass ramp to I-271 South-Richfield.

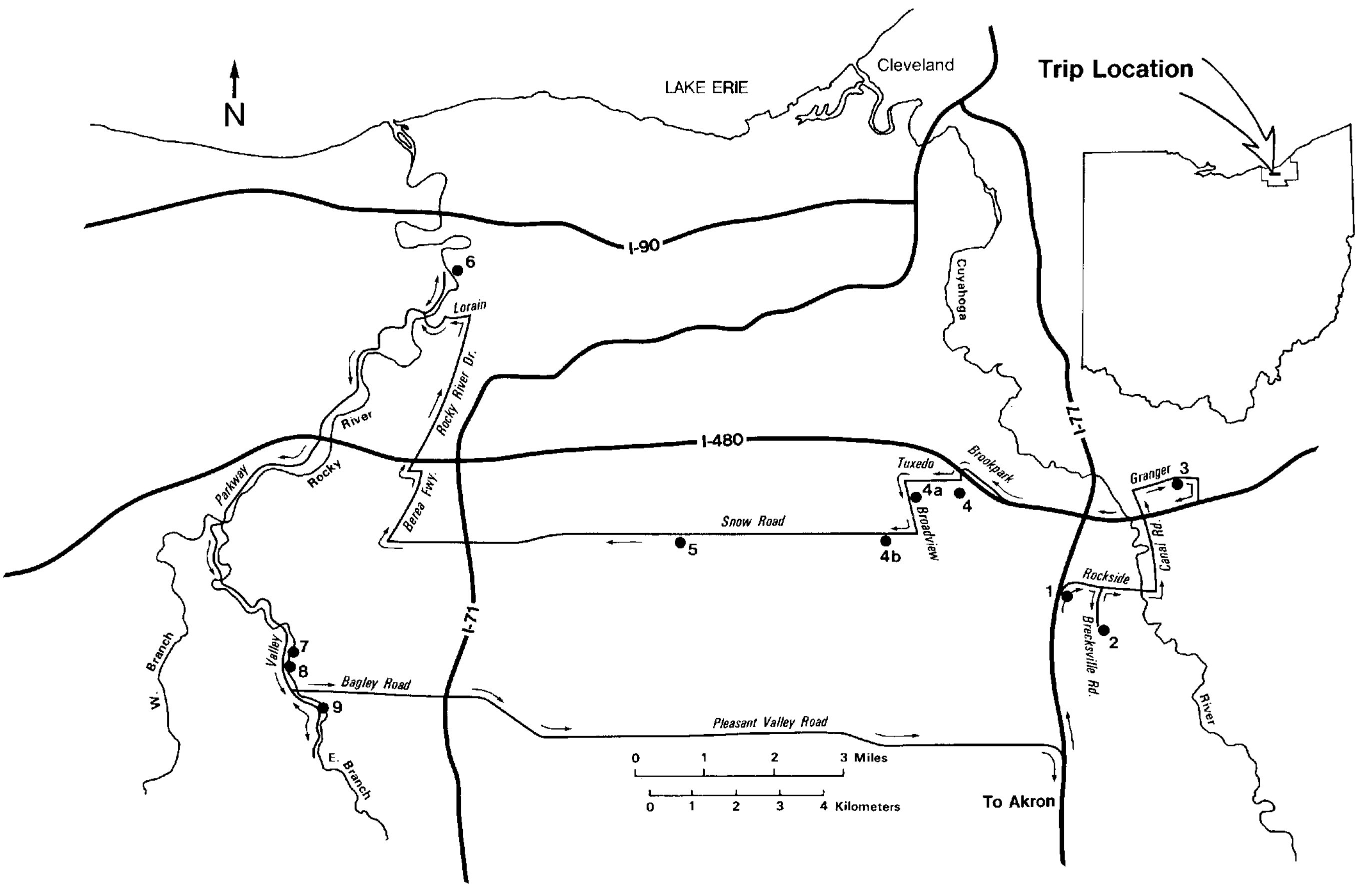

FIGURE 8. Field trip route map and stop locations.

28.5	(17.7)	0.8	(0.5)	Pass ramp to I-271 North-Erie.
39.4	(24.5)	10.9	(6.8)	View right of the Orangeville Shale. This shale and the Sunbury Member form the top of the stratigraphic section we will observe.
43.5	(27.0)	4.0	(2.5)	View right of the Cuyahoga River valley and part of the Allegheny Plateau.
43.9	(27.3)	0.5	(0.3)	Pleasant Valley Rd. Overpass.
47.5	(29.5)	3.5	(2.2)	Stay right, slow down as you approach ramp to Rockside Rd. Park right just before exit ramp.

STOP 1. SE 1/9 of the Cleveland South 7.5 minute quadrangle.

Lower Berea Sandstone, Bedford-Berea contact, red shale sandwiched between gray shale and lower gray shale and silts.

Berea sandstones, in conformable contact with gray shales of the upper Bedford, display large-scaled, stacked cross-beds and occasional plane-beds through about 4 m of section (Fig. 10). This rare transverse section of a channel-like body displays constructional style deposition. Small faults outline one edge (Fig. 11). Cross-beds are oriented S 70-80° W, quite rare for Berea units on the plateau. Also, some of the coarsest average particle sizes (0.3-0.35 mm — medium sand) seen in any of the Berea are represented in these moderately sorted sandstones. Shale interlayers are absent. Occasional red-stained zones outline bedding planes.

A second contact is seen around the bend (exit ramp). Three meters of sandstone rest evenly on gray shales. Some horizontal beds occur but most are cross-beds, some with a northwest orientation. Red shale, 4 m thick, underlies the gray shale. Some red laminae interfinger with gray siltstones exposed in the drainage ditches.

48.1	(29.9)	0.6	(0.4)	Follow exit ramp. Turn right onto Rockside Rd.
48.9	(30.4)	0.8	(0.5)	Turn right onto Ohio 21 (Brecksville Rd.) and climb the hill.
50.1	(31.1)	1.1	(0.7)	Park in parking lot (left) at top of hill. Walk partly back down hill on the east side of Brecksville Rd.

STOP 2. NE 1/9 Cleveland South 7.5 minute quadrangle.

Plane bed and tangential cross-beds of the upper Berea Sandstone.

The large-scaled tangential cross-beds, overlying horizontal plane-bed and rippled sands, form an attractive base for the wall (Fig. 12). Such cross-bed units are characteristic of the upper Berea Sandstone. Most exceed

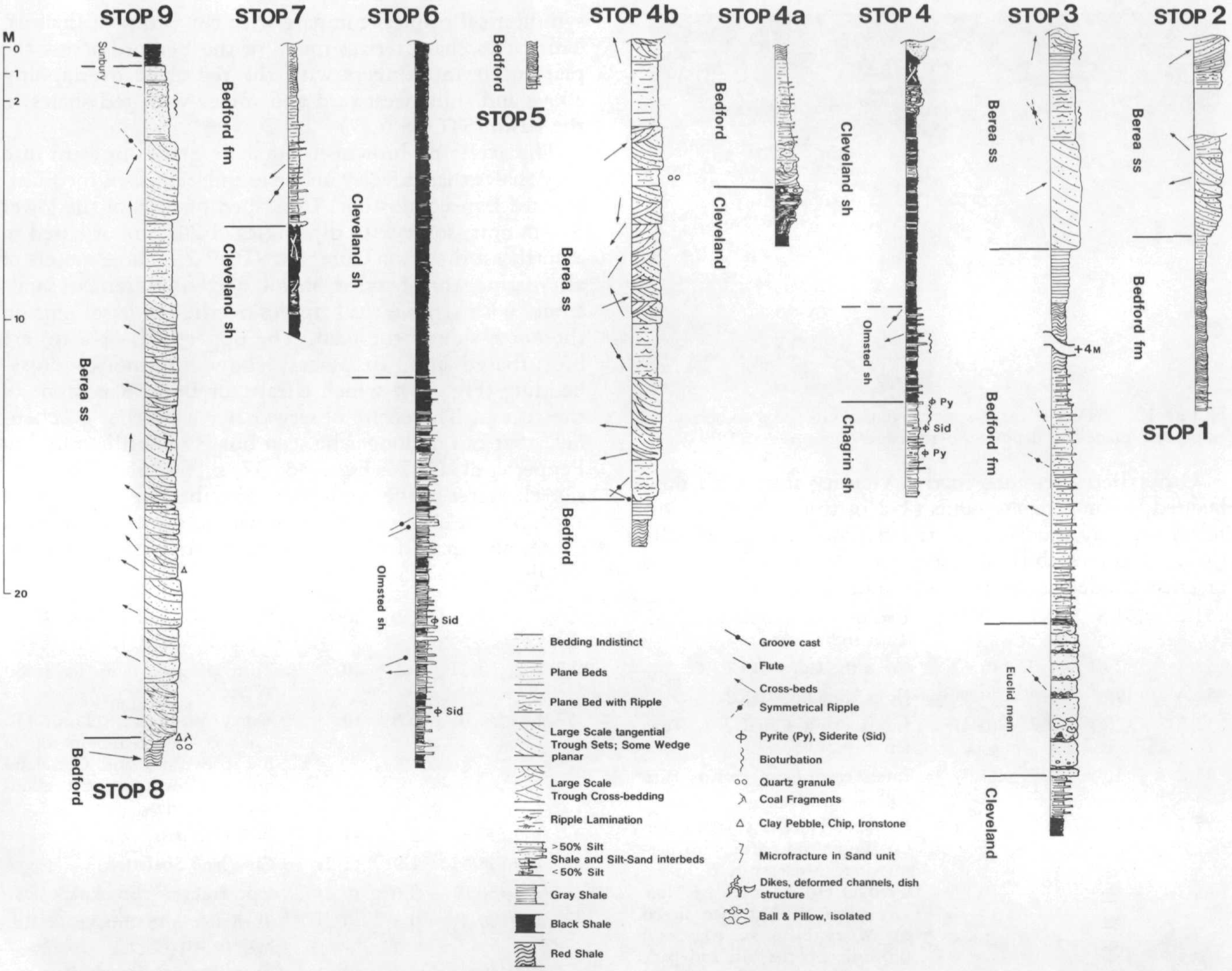

FIGURE 9. Stratigraphic sections at various field trip stops.

FIGURE 10. STOP 1. Large-scale trough cross-beds in transverse section, Berea Sandstone.

FIGURE 11. STOP 1. Irregular, faulted margin (channel edge?), Berea Sandstone.

1 m in thickness. They are comprised of well sorted medium sands; interbedded mud drapes are rare; and, in these areas of the plateau, cross-bed foresets are oriented northeast. Cross-bed units are separated by horizontal beds that consist mostly of symmetrical ripples with occasional interference, double-crested and flat-topped ripples. Bioturbated mud laminations and beds may separate individual ripple beds. The cross-beds may represent subtidal sand waves or shallow shelf bars and ridges.

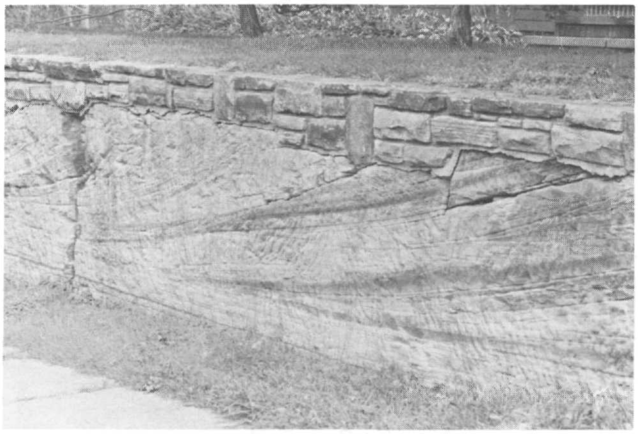

FIGURE 12. STOP 2. Large-scale tangential crossbeds on horizontal ripple and plane-bed deposits, Berea Sandstone.

Other Berea sections in this vicinity start with non-bedded, homogeneous sands (1-2 m thick) that rest directly on gray mudshale of the Bedford. These initially fluidized beds stabilized, then were covered with rippled or cross-bedded sands that were not disrupted.

51.2	(31.8)	1.1	(0.7)	Return (north) to Rockside Rd. Turn right.
52.1	(32.4)	1.0	(0.6)	Cross the Cuyahoga River.
52.3	(32.5)	0.2	(0.1)	Cross the Ohio Canal.
52.5	(32.6)	0.2	(0.1)	Intersection Canal Rd. Turn left.
55.2	(34.3)	2.7	(1.7)	Intersection Granger Rd. Turn right.
55.7	(34.6)	0.5	(0.3)	Entrance Horvitz Construction Co. Enter and park, with permission. Must turn right on Granger Hill as you leave Horvitz entrance. Entrance closed on weekends so proceed 0.6 mile up the hill and park at intersection of Granger and E. 98th St. Walk downhill to outcrops.

STOP 3. W 1/9 of Shaker Heights 7.5 minute quadrangle. E 1/9 Cleveland South 7.5 minute quadrangle.

Cleveland Shale, Bedford Formation with Euclid Member, Berea Sandstone.

This easily accessed road cut records a complete section of the variable Bedford Formation and partial sections of the Cleveland Shale and Berea Sandstone. The Euclid Member of the Bedford is separated from the Cleveland black shales by 1.5 m of gray shale with fossils and thin siltstone beds. It is comprised of nearly 6 m of siltstone and very fine-grained sandstones from 0.1 to 1.2 m thick. Indistinct lamination, massive bedding, and conchoidal fracture are common. Load casts, contorted shale interbeds (some rapped around ball-and-pillow structures), and beds that separate and become discontinuous suggest rapid emplacement. Occasional symmetrical ripples occur on thin silts beneath thick massive units.

Ten meters of the gray shale-siltstone facies overlies the Euclid. Siltstones, from 2-8 cm thick, display cross and wavy-lamination, load casts, small groove-casts, and symmetrical ripples (compare with thin units of Euclid). This facies characterizes much of the Bedford across the plateau. It interfingers with the red shale overlapping above and thins westward and mixes with red shales in the basin (STOPS 5, 7).

The overlying brownish-red shale grades upward into gray shales that directly underlie thick units of medium-grained Berea Sandstone. Cross-bed foresets of the lower 3-4-m unit, some with dip angles of 24°, are oriented in a northeast direction (compare STOP 2). Three meters of alternating thin-bedded shales and fine-grained sandstones with symmetrical ripples overlie the basal unit on the north side of the road. The upper beds (1-2 m) are bioturbated and, in places, show hummocky cross-bedding (Fig. 13), which is rare for Berea Sandstone of the region. The entire observed Berea overlies a "channel" that can no longer be seen but is well illustrated in Pepper et al. (1954; Figs. 36, 37, p. 64, 65). The massive character of the sands they describe along with what appears to be a step-faulted eastern margin of the channel is reminiscent of deformation characteristics described at STOPS 1, 2.

56.6	(35.2)	1.0	(0.6)	Turn right into E. 98th St. at top of hill. Stay left.
57.1	(35.5)	0.5	(0.3)	Turn left into ramp for I-480 West.
57.9	(36.0)	0.8	(0.5)	Valley View Corp. Limit. To right is the Euclid on top of lower Bedford and Cleveland Shale. Downtown Cleveland skyline in view.
60.0	(37.3)	2.1	(1.3)	I-77 Overpass.
62.0	(38.5)	1.9	(1.2)	Cleveland Shale left.
62.6	(38.9)	0.6	(0.4)	Exit right to Brookpark Rd.
62.9	(39.1)	0.3	(0.2)	Turn left into Brookpark Rd. Stay to left.
63.4	(39.4)	0.5	(0.3)	Turn left into Tuxedo Rd.
64.1	(39.8)	0.6	(0.4)	Enter Brooklyn Heights Park. Park at bottom of hill.

STOP 4. S 1/9 Cleveland South 7.5 minute quadrangle.

Chagrin Shale, Cleveland Shale (including Olmsted Shale). Dikes

FIGURE 13. STOP 3. Hummocky cross-bedding (1.0 m thick) over bioturbated sands at top of Berea sandstone, Granger Road.

and deformed siltstone units of lower Bedford Formation.

A complete (12.2 m) Cleveland Shale section sharply but conformably overlies 4 m of Chagrin Shale. Gray mudshales, occasional siderite pods, and very thin, often discontinuous, massive (bioturbated) silts characterize the Chagrin. The thin, cross-laminated, grooved silts with prodcasts and conical-shaped burrow structures in the Olmsted Shale (lower 3.2 m) of the Cleveland stand in marked contrast to those of the Chagrin. Grooves unusually mark the tops of some silts (Fig. 14). A thin (1-10 cm) lens of pyrite nodules, shale, plant fragments, and abraded fishbone plates (Skinner's Run Pyrite Bed) separates Chagrin shales from 20-40 cm of black shales of the Cleveland. The top of the Cleveland section is loaded with siltstone lenses, isolated ball-and-pillows, and siltstone dikes (Fig. 15). A deformed siltstone-filled channel occurs at the top of the stream tributary.

Silts of the Chagrin may represent storm layers deposited below wave base at the distal margin of the clastic wedge. The Olmsted silts may represent small turbidites generated and modified by storm impulses. Directional azimuths of grooves (S 40° W) suggest that currents moved roughly parallel to the paleoslope of the outer Chagrin wedge. Suggested origins of the pyrite lens include a nearshore lag deposit (Hlavin 1976), a deeper water lag zone in areas of nondeposition (Mausser 1982), or a storm-generated concentrate.

Rapidly emplaced infusions of Euclid silts and sands, directed toward the deeper basin, created concomitant soft-sediment deformation structures in basinal black muds.

64.4	(40.0)	0.3	(0.2)	Leave park. Turn left into Tuxedo Ave.
65.5	(40.7)	1.1	(0.7)	Turn left into Broadview Rd.
66.0	(41.0)	0.5	(0.3)	Turn left into Bamboozles Restaurant parking lot. Park at rear of lot. Walk east to stream bed.

STOP 4. Alternate 4A, B: S 1/9 Cleveland South 7.5 minute quadrangle.

Cleveland Shale with deformed Bedford silts. Dikes, ball and pillows, microfaulted silt lenses, dish structure, deformed "channels".

Alternate 4A will be used in case of high water at STOP 4. This section continues the deformed zone seen at top of the section at STOP 4. It demonstrates continuing deposition across the Cleveland-Bedford (systemic?) boundary. There are excellent examples of deformed "channels" (Fig. 16), ball-and-pillow structures,

FIGURE 14. STOP 4. Grooves recording flow directions on top (rare) of siltstone units, Olmsted facies of Cleveland Shale.

FIGURE 15. STOP 4. Exposed edge and surface of siltstone dike injected in upper Cleveland black shales. Arrows point to crenulated molds and curved surfaces that contained silts.

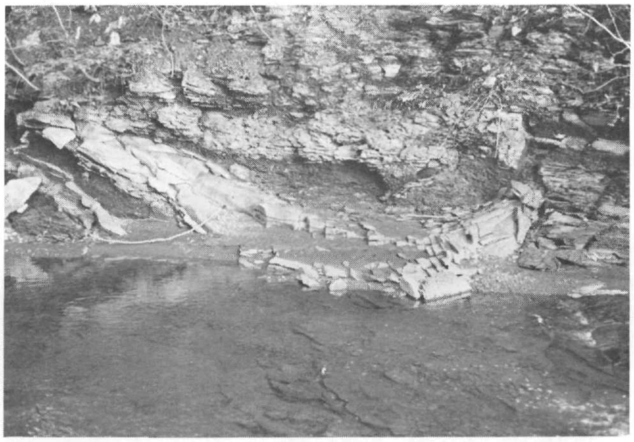

FIGURE 16. ALT. STOP 4. Bedford siltstones of deformed channel-like configuration in Cleveland black shales. Note inclined layers and siltstone dike at left.

small overturned folds in silts, a host of twisting dikes with exposed edges and crenulated (stretched?) surfaces and crenulated molds in black shales, microfaulted silt lenses with bulbous top surfaces, dish structure in a "channel", and symmetrically-rippled sands building up into ball-and-pillows (Fig. 17).

Alternate 4B, accessed (with difficulty) below the Snow Road bridge, completes the Skinner's Run section with 17 m of Berea Sandstone over gray and red mud-shales of the upper Bedford. Only small undulations occur at the contact. Basal sands in one shows flute-casts (Fig. 18) that formed in probable sub-marine flows. These beds are overlain by horizontal, symmetrically rippled beds produced in open shelf waters. The remaining section is comprised of large-scaled cross-beds and some ripple and plane-bed horizons. Cross-bed orientations show perhaps the most varied orientations of any Berea outcrop of the region (Fig. 9, STOP 4B).

66.1	(41.1)	0.2	(0.1)	Turn left into Broadview Rd.
66.9	(41.6)	0.8	(0.5)	Turn right into Snow Rd.

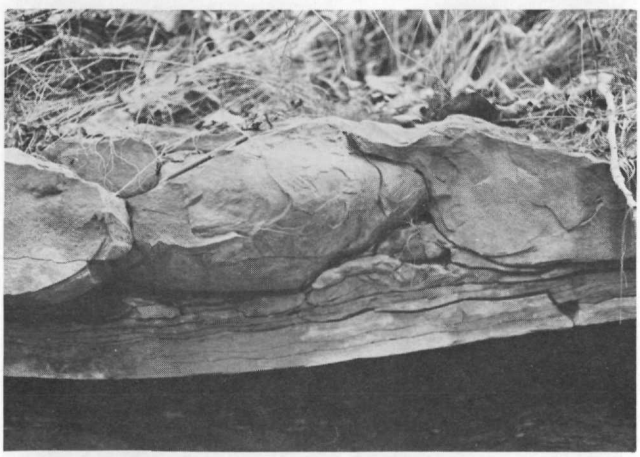

FIGURE 17. ALT. STOP 4A. Ball-and-pillow structure built over symmetrically-rippled beds of sandy silts with mud laminations (partings), Bedford-Cleveland contact.

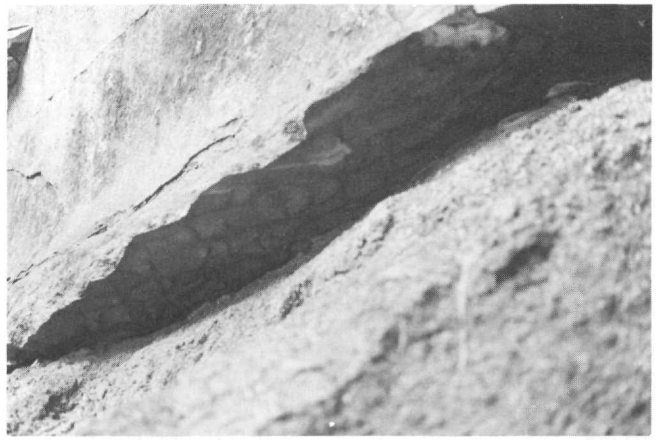

FIGURE 18. ALT. STOP 4B. Flute-casts on base of Berea sandstone, Bedford-Berea contact. Direction of currents from right to left (or N 70° W in the basin).

67.6	(42.0)	0.6	(0.4)	Cross Skinner's Run (Quarry Creek). Bridge rests on the Berea Sandstone. Unusual Berea section was initiated with flute casts followed by symmetrically rippled beds and then by large-scaled cross-beds with highly variable directions.
71.5	(44.4)	3.9	(2.4)	Cross Pearl Rd.
72.6	(45.1)	1.1	(0.7)	Turn left into Metropark just before Hauserman Rd.
72.7	(45.2)	0.2	(0.1)	Turn left into picnic area.
73.1	(45.4)	0.3	(0.2)	Cross ford, park right at Pavilion.

STOP 5. SE 1/9 Lakewood 7.5 minute quadrangle.

Bedford Formation. Interfingering gray silts and red shales.

Lunch is served. Also, one can observe approximately 6 m of red mudshale. Importantly, thin siltstones and gray silt laminations are intercalated with the basal section of the red mudshale suggesting time equivalency. Small-scaled ripple units may be turbidites, perhaps generated by storms and moved into the basinal red muds.

73.5	(45.7)	0.5	(0.3)	Return to Snow Rd. Turn left. Cross Hauserman Rd.
76.0	(47.2)	2.4	(1.5)	Cross West 130th St.
78.9	(49.0)	2.9	(1.8)	I-71 Overpass.
80.5	(50.0)	1.6	(1.0)	Intersection Ohio 237. Turn right (North).
81.8	(50.8)	1.3	(0.8)	Stay right. Follow Ohio 237 to right (Lakewood, Berea).
82.2	(51.1)	0.5	(0.3)	Turn left into Brookpark Rd.
82.6	(51.3)	0.3	(0.2)	Turn right into Rocky River Drive.
82.7	(51.4)	0.2	(0.1)	I-480 Overpass.
84.5	(52.5)	1.8	(1.1)	Cross Puritas Rd.
86.4	(53.7)	1.9	(1.2)	Turn left into Lorain Ave.
86.7	(53.9)	0.3	(0.2)	Turn left into far left fork — Riveredge Dr. (not Groveland).

86.9	(54.0)	0.2	(0.1)	Stay right and enter narrow road just behind garage of Fairview Hospital.
87.4	(54.3)	0.5	(0.3)	Little Met. golf course at base of hill. Cross bridge.
87.5	(54.4)	0.2	(0.1)	Turn right into main park road.
87.7	(54.5)	0.2	(0.1)	Drive under Lorain Ave. bridge. Bridge level represents the proglacial Lake Whittlesey (about 13,300 B.P.)
89.0	(55.3)	1.3	(0.8)	Cross bridge. Park right.

STOP 6. N 1/9 Lakewood 7.5 minute quadrangle.

Cleveland Shale, mainly the Olmsted Shale.

This 26.5-m section of the Cleveland Shale is represented by 14.1 m of thin to thick-bedded siltstones intercalated with dark gray and black shales overlain by 12.4 m of black shale with thin silt and gray shale units and occasional limestone lenses with cone-in-cone structures. The lower siltstone shale sequence, often mapped as Chagrin, is the Olmsted Shale of the Cleveland. Estimated thickness, in this vicinity is 16 m, approximately five times greater than that at STOP 4. Siltstones comprise over 50% of the section and display examples of flute casts, groove-casts, swaley cross-stratification, ripple drifts, some graded beds building upward to parallel and cross-lamination (partial Bouma turbidite cycle), horizontal burrows and traces, occasional vertical burrows, and rare convolute laminae (Fig. 19). Cross-stratification directions are variable in some units, quite consistent in others (swaley types), and often variable to orientations of basal bedding-plane structures. Probably some traction modification by existing or secondary currents took place in the basin. The Olmsted grades upward into increasing amounts of black shales, with thin intercalated gray and dark gray mudshales.

90.1	(56.0)	1.1	(0.7)	Return south. Lorain Ave. bridge.
90.4	(56.2)	0.3	(0.2)	Little Met. golf course. The valley widens considerably since it cuts through glacial tills of a preglacial valley.

FIGURE 19. STOP 6. Siltstone turbidite over dark gray shales, Olmsted facies of Cleveland Shale. Note the small flutes and groove-casts on bottom. Lower siltstones show the more characteristic swaley cross-stratification. Current directions are towards the viewer.

90.8	(56.4)	0.3	(0.2)	Old landslide on right. This was generated in tills.
93.5	(58.1)	2.7	(1.7)	Puritas Rd. stoplight.
94.6	(58.8)	1.1	(0.7)	Landslide to right. This was generated in the Cleveland Shale.
95.4	(59.3)	0.8	(0.5)	Bridge overhead—I-480.
99.3	(61.7)	3.9	(2.4)	Cross Lewis Drive and east branch of Rocky River. Cliffs in vicinity are entirely Cleveland Shale.
99.8	(62.0)	0.5	(0.3)	Lagoon to the right is part of meander loop of an oxbow lake. Main stream is on left side of road.
100.7	(62.6)	1.0	(0.6)	Cross ford. Cleveland Shale exposed.
103.5	(64.3)	2.7	(1.7)	Start hill climb through Bedford Shale to Berea Sandstone at top.
103.8	(64.5)	0.3	(0.2)	Park left at "Slide Hill."

STOP 7. SE 1/9 Lakewood 7.5 minute quadrangle.

Tilted Cleveland-Bedford contact, siltstone ball and pillows and dikes in the Cleveland Shale, deformed Bedford gray shales and siltstones below red shales.

Another Cleveland-Bedford contact is seen that can be compared to STOPS 3, 4, 4A. The Cleveland is represented by 4 m of black shale with small siltstone ball-and-pillows and thin dikes in black shales. A 20-cm-thick siltstone with loadcasts initiates the main Bedford followed by 3.4 m of gray shale and thin siltstones that decrease in frequency upward. The overlying gray shale (1.8 m thick) grades upward into red mudshale. Thin silts (like those seen at STOP 5) are missing in this gray shale zone. Except for the initial bed and deformed siltstones (which might represent Euclid equivalency), most of the siltstone sequence is equivalent to the silt-shale facies described at STOP 3.

The Cleveland contact dips to the southwest toward thick sections of the Berea Sandstone exposed 0.3 km upstream. Such dips occur along most Cleveland-Bedford contacts and within the Cleveland shales near thick sections of Berea west of the Cuyahoga River. An overturned fold and normal and reverse faults in this section are interpreted as adjustments in deeper parts of the section related to rapid input and thick accumulation of easily moved fine- and medium-grained sands of the Berea (Fig. 20).

104.3	(64.8)	0.5	(0.3)	Proceed south (left). Park left near "Overlook".

STOP 8. SE 1/9 Lakewood 7.5 minute quadrangle.

Berea Sandstone and Bedford contact.

The lower 13 m of a 24.5-m Berea composite section (Fig. 9) is exposed and rests on gray shale overlying red

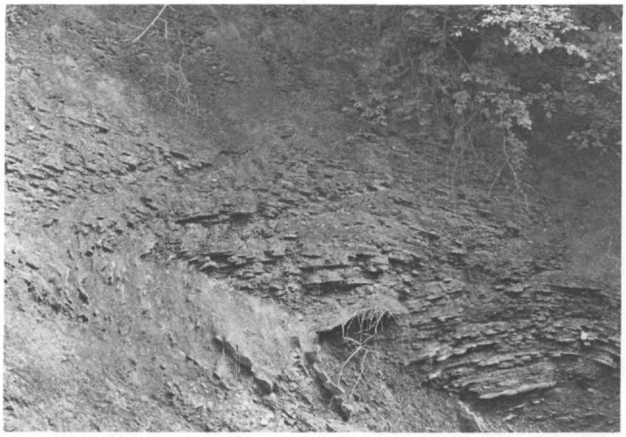

FIGURE 20. STOP 7. Overturned fold in the lower Bedford gray shales and siltstones. These units grade upward into gray shales followed by red shales (out of view).

shale. Most of the Berea is medium-grained lithic sand except for a local basal zone of coarse-grain particles and granules. Coal fragments are locally represented at the contact. Rip-up shale clasts are represented at several horizons. Large scaled cross-beds (0.2-1.5 m) with northwest orientations dominate the section. A microfaulted, 1.8-m, cross-bedded unit with foreset slopes directed north appears near the top of the section. Small-scaled, cemented, normal faults puncture the Berea. Many are close-spaced with adjustments of a few centimeters. Others extend several meters above the contact. In addition to soft-sediment adjustments, later stage faulting controlled the sharp step-like configuration of the contact as well as a "channel" margin (Fig. 21).

104.6	(65.0)	0.3	(0.2)	Bridge underpass. 11′6″ clearance.
105.1	(65.3)	0.5	(0.3)	Cross Bagley Rd. Proceed south on Barrett Rd.
106.1	(65.9)	1.0	(0.6)	Pass under bridge and pull over to right at bare spot. Walk south to bridge and road outcrops.

STOP 9. NW 1/9 Berea 7.5 minute quadrangle. Upper Berea Sandstone and transition to the black shale of the Sunbury.

This upper part of the composite section of the Berea (Fig. 9) features shelf sands comparable to those seen at STOPS 2 and 3. Also, it is the only section showing the transition to overlying black shales (Sunbury) west of the Cuyahoga River. Two meters of friable, medium-grained sand comprise the large-scaled, cross-bed foresets which are oriented about N 05° W (Fig. 22). Thin, rippled (N 45° W trend), fine-grained sands with shale partings truncate the foresets. This is followed with thin, medium-grained sands with shale interlayers that grade upward into discontinuous fine sands and siltstones with 10-12-cm-thick shale interbeds. Load casts, occasional ball-and-pillow, and rare symmetrical ripple (N 80-85° W) occur in the silts. Increasing amounts of gray shale grade upward into black shales. A thin sand wedge locally interrupts the black shale. This sequence records deepening shelf waters coupled with rapid cutoff or diversion of sand supply.

FIGURE 21. STOP 8. Multiple normal faults cut horizontal beds and define adjustments parallel to "channel" edge, Berea sandstone.

FIGURE 22. STOP 9. Large scale tangential cross-beds truncated by plane and rippled beds, Berea sandstone.

106.7	(66.3)	0.6	(0.4)	Proceed south. View lakes filling abandoned quarries. Turn around and return to Bagley Rd.
108.3	(67.3)	1.6	(1.0)	Turn right into Bagley Rd. Follow Bagley Rd. to Pleasant Valley Rd. and continue to the exit for I-77 South.
127.0	(78.9)	18.7	(11.6)	Turn right off Pleasant Valley Rd. into ramp for I-77 South.
170.9	(106.2)	43.9	(27.3)	Return to Akron.

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